DESIGN OF A HYDRO - ELECTRIC STEAM POWER PLANT

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DESIGN
OF A
1500 K.W. HYDROELECTRIC
AND
AUXILIARY STEAM POWER PLANT

A THESIS

PRESENTED BY

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INDEX.

DRAWINGS.

SOUTH ELEVATION

PLAN

SECTIONAL ELEVATION

SECTION GENERATOR ROOM

SECTION TURBINE ROOM

ELEVATION 33,000 VOLT BUS BARS

SWITCHBOARD

OIL SWITCHES

WIRING DIAGRAM

DETAIL OF BOILER AND SETTING

DETAIL OF 50 KW. TURBO-EXCITER

DETAIL OF 50 KW TURBO-EX

PROJECT.

The design is to be of a water power plant of 1500 K. W. capacity with an equal auxil iary steam plant. This is to supply power to a 33,000 volt feeder, a 2,300 volt light and power feeder and a series arc circuit at Marseilles, Illinois. The ultimate capacity of the plant is to be 3,000 K.W.

Local Conditions:

The plant is to be located on the Illinois river at Marseilles, where there is a dam providing a head of fourteen feet. Water from above the dam is diverted through two headraces and supplies power to a number of manufacturing plants. The new plant will be located on an extension of one of these headraces. Part of the concrete foundation has been constructed which limits the design to vertical type water wheels.

During the winter months, the water power is very uncertain and at times is altogether stopped, making the installation of an auxil iary plant a necessity.

BUILDING.

The building is 140 feet long by 60 feet wide. A fire wall divides the boiler room which is 40 feet by 60 feet, from the remainder of the building. A separate foundation is provided for the generators and the boilers. The building foundation which also forms the retaining walls will support the other machinery.

The generator room is located over the spillway. There are three separate turbine pits divided by concrete walls which extend from the north end of the building to the condenser pits on the south end. These walls will support the water turbines and the turbo-generator sets with their condensers.

Support for a 15 ton crane will be provided by columns located in and forming part of the walls.

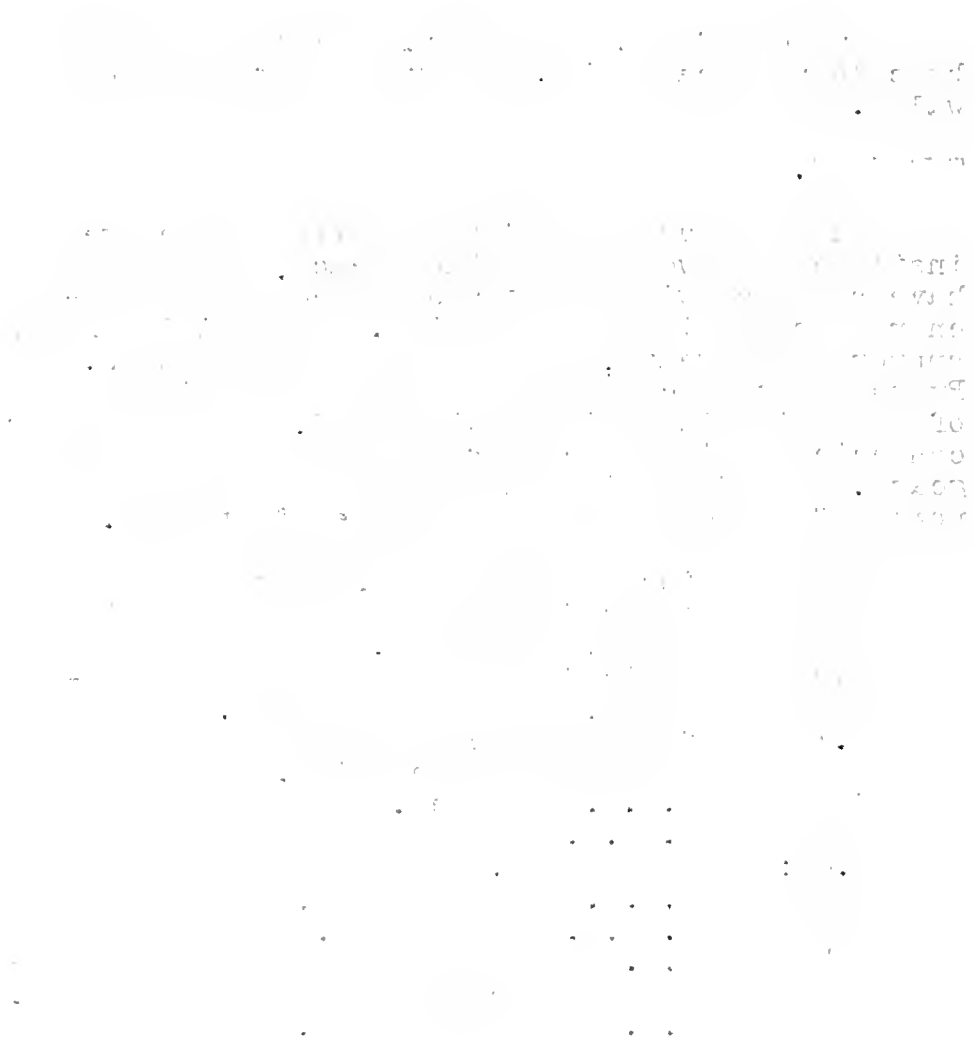
TURBINES.

Sampson turbines of the vertical type are installed in two sets of three each. These walls have balanced wicket gates operated by the govenor as shown in the plan view. A special harness supports the gears, line shaft and gate stems. By use of this continuous harness the alignment of the units is rigidly maintained. The wheels are connected to the generators by means of bevel gears. The following data shows the size and power of the wheels for a fourteen foot head.

74	inch diameter of runner
27040	cubic feet of water used per minute, per wheel.
54080	cubic feet of water used per minute, in each wheel pit.
5.1	feet per second equals velocity of water in wheel pits.
82	R.P.M. of wheel.
200	R. P.M. of generator
2.44:1	gear ratio.
580	D.H.P. of each wheel.
1740	D. H.P. of each set.
1570	H.P. available per line shaft assuming efficiency of gears equal 90%.
3140	H.P. total available.

Each line shaft will supply power to a 750 K.W. alternator and an oil pump for the govenor. Power from either line shaft will also operate a 50 K. W. exciter.

The arrangement of the wheel pits is such that any pit can be closed as there are separate gates for each, thus cutting off one turbine from each shaft. This allows repairs to be made on the wheels without shutting down the plant or starting the auxilliary plant. When operating under this condition of two wheels per line shaft, the power ratings will be as follows:



1160 D.H.P. by two wheels.
1045 H.P. available per line shaft assuming the efficiency of the gears to be 90%.
2090 H.P. total available.

This will decrease the velocity of the water in the headrace but not in the wheel pits.

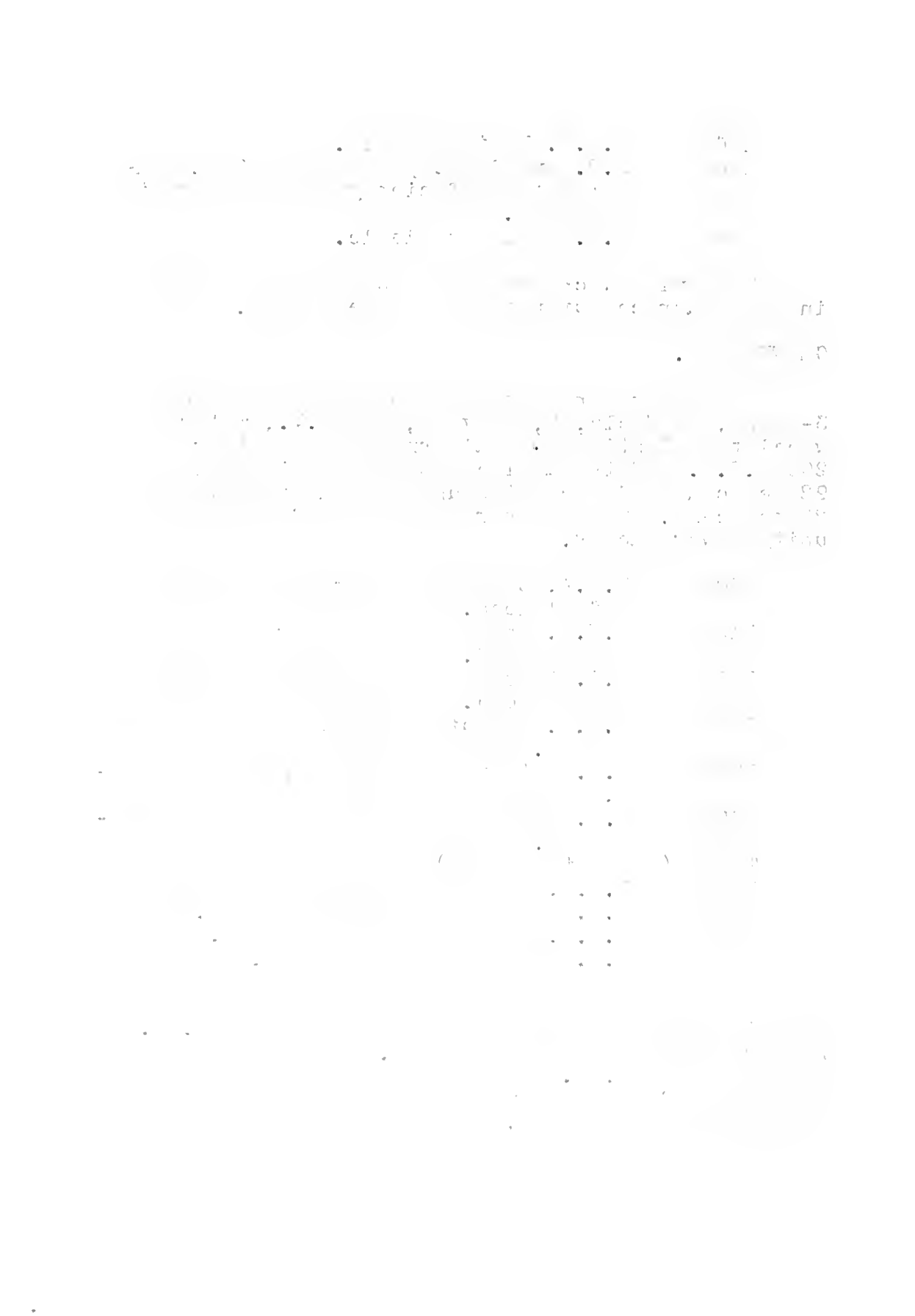
GENERATORS.

The generator installation consists of two 3-phase, 60 Cycle, 2,300 volt, 750 K.V., water wheel type Westinghouse altermators operating at 200 R.P.M. This machine has an efficiency of 92 per cent and a continuous overload capacity of 25 per cent. The power rating is as follows on unity power factor.

750 K.V.A. output / generator at normal full load.
815 K.V.A. input / generator at normal full load.
1090 H.P. input / generator at normal full load.
940 K.V.A. output / generator at 25% overload.
1260 H.P. output / generator at 25% overload.
1370 H.P. input / generator at 25% overload.

Total (Two alternators)
1500 K.V.A. output at normal full load
2180 H.P. input at normal full load.
1880 K.V.A. output at 25% overload.
2740 H.P. input at 25% overload.

Allowing one hundred horsepower for the exciter and oil pumps there will be a total of 2840 H. P. required for a possible maximum. This leaves a margin of 300 H. P. which will allow for a slight reduction of head and will also give the govenors more freedom of action.



EXCITERS.

The excitation for the alternators is supplied at 125 volts from any of three separate units, each of 50 K. W. capacity. One unit is belt driven from either of the main shafts at 850 R. P. M. When operating by steam, the excitation is supplied from a 50 K. W. turbo-generator set, run noncondensing. A 50 K. W. Westing house motor-generator set is installed as a reserve unit.

AUXIL IARY MACHINERY.

Lombard Type "N" govenors are used for regulating the turbine speed. In this type of govenor, the oil pump, tanks and govenor proper can be separated which allows a more suitable arrangement to be made.

The 33,000 volt line is supplied from three single phase, 400 K. W., oil cooled Westinghouse transformers connected in delta on both; the primary and secondary side. The ratio of transformation is 2,300 to 33,000 volts. The transformer bank is connected to the bus bars by means of a Westinghouse type "B" manually operated non-automatic oil circuit breaker. The secondary is connected to the line by means of a Westinghouse type "C" solenoid operated automatic oil circuit breaker. Choke coils in conjunction with electrolytic cell lightning arresters protects the station apparatus from outside disturbances.

The arc light circuit is supplied from a 50 light capacity constant current regulator. Oil switches are used on the panel which is separate from the main board. The primary switch is double pole and double throw, so that the arc load can be placed on either of two phases.

SWITCHBOARD.

The switchboard is 95 inches high, and 16 feet 6 inches in length, and follows the Westinghouse practice. The oil switches, bus bars, and instrument transformers are placed on a separate structure away from the board. The field rheostats are remote controlled and are placed on the wall above the bus bars. All oil switches are manually operated excepting the 33,000 volt switch which is solenoid operated. The arc light panel is placed near the

constant current regulator as the 2,300 volt wires are brought direct to the back of the panel. All wiring is in conduit excepting 33,000 volt wires. Following is a list of the switchboard instruments.

Generator Panels. (Four)

1 type F A.c. ammeter.
1 type F plyphase wattmeter.
1 type D field ammeter.
1 ammeter receptacle.
1 voltmeter receptacle.
1 synchronizing receptacle and lamp.
1 field switch with discharge attachment.
1 field rheostat.
1 type B non-automatic oil circuit breaker.

Single Exciter Panel.

1 type K d.c. ammeter.
1 field rheostat.
1 type D d.p.s.t. knife switch.

Double Exciter Panel.

2 type K d.c. ammeter.
1 type K d.c. voltmeter.
1 eight point voltmeter receptacle.
2 field rheostats.
2 type D d.p.s.t. knife switch.

Regulator Panel.

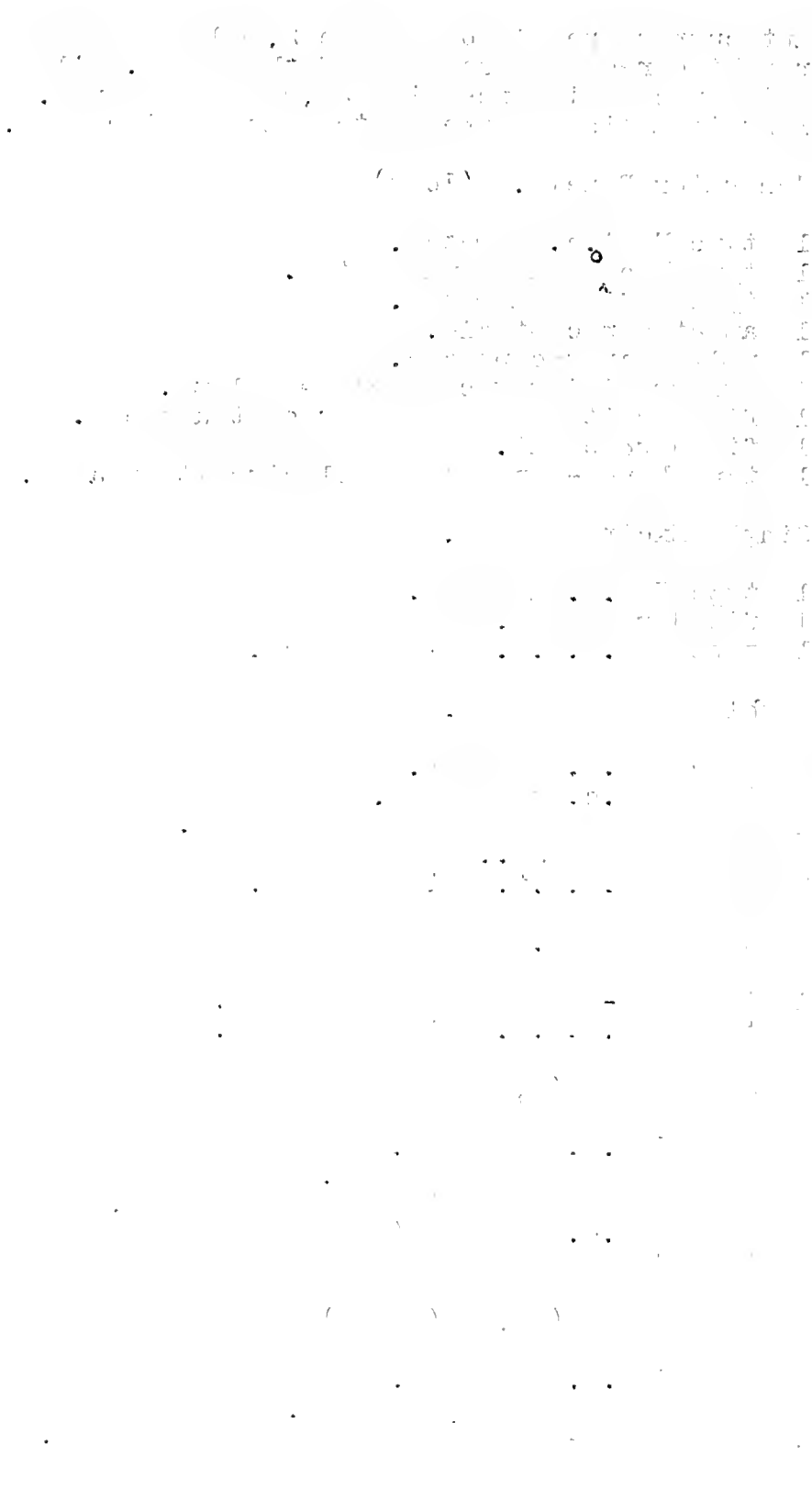
1 type T A-125 voltage regulator.
2 type D d.p.d.t. knife switches.

Feeder Panel (2,300 volts)

3 type I a.c. Ammeters.
1 type polyphase wattmeter.
1 type B automatic oil circuit breaker.
1 type I a.c. ammeter (station lights)
1 type B automatic oil circuit breaker (station lights)

Feeder Panel (33,000(volts)

3 type I a.c. ammeters.
1 type I polyphase wattmeter.
1 type B non-automatic oil circuit breaker.



1 controlling switch for 33,000 volt type C automatic oil circuit breaker.

indicating lights.

Arc Light Panel.

1 type F a.c. ammeter.
1 type D d.p.d.t. oil switch.
1 type D combination d.p.s.t. and s.p.s.t. oil switch.

AUXILIARY STEAM PLANT.

The steam plant duplicates the water power plant in capacity.

BOILERS.

The boiler plant consists of three 315 H. P. type "S" Sterling boilers fitted with Green chain grates and operating at 150 pounds pressure. Two of the boilers are in a twin setting and the third setting joins the fire wall between the turbine room and the boiler room. The stokers are operated by a Wachs disc crank engine which exhausts into the main exhaust header.

Coal is dumped directly from cars onto the boiler room floor, through windows in the north wall. No bunkers nor downspouts are used.

A detail of the boiler, its setting, grate and foundation is shown in an accompanying drawing.

MECHANICAL DRAFT.

An induced draft system is installed, owing to the cost and the necessity of overload capacity. The blower is manufactured by the American Blower Company andis full housed, top vertical discharge, steel plate fan. The wheel has a diameter of 108 inches and a width of 42 inches. At 250 R. P. M. the fan will discharge 77,000 cubic feet of flue gas per minute at 550° F giving about one ounce per square inch draft. Under these conditions about 30 B. H. P. is required.

The blower is operated by a 9"x8" American Blower Company vertical, enclosed self oiling engine fitted with an outboard bearing on which the fan wheel is supported. This engine exhausts into the main exhaust header.

plant in capacity.

BOILERS.

PUMPS.

Two Marsh steam pumps are installed; a 6"x 8"x 12" low service pump supplying cold water to the feed water heater, and a 12"x 8"x 12" boiler feed pump taking water from the heater or directly from the main supply and discharging to the boiler feed line. The pumps each have a capacity of 15,600 gallons per hour with discharge pressures of 30 and 150 pounds per square inch respectively, and a maximum back pressure of 2 pounds per square inch.

FEED WATER HEATER.

A Vater open feedwater heater of 1000 H.P. rating is installed. It is piped so that all or a part only of the exhaust steam may be passed through it. The heater is of the vertical, cylindrical, boiler iron type, not a cast heater. It is supplied with a 10 inch exhaust steam oil separator, and has the usual cleaning doors, water level regulating devices and other appurtenances common to the open type of heater.

Exhaust steam is supplied from all of the steam using apparatus with the exception of the two 750 K. W. turbo-generator sets.

TURBO-GENERATORS.

The steam generating apparatus consists of two 750 K. W. Westinghouse Parsons turbo-generators, running at 3,600 R. P. M. and furnishing 3-phase alternating current at 2,300 volts. The two units are placed along the south wall of the wheel room. This allows space for condenser pits below the turbines without obstructing the head race. The turbines are supported by six 15 inch I-beams which are in turn supported by 24 inch I-beams and the south retaining wall. The 24 inch I-Beams are supported on extensions of the wheel pit walls.

The exciter turbine is operated non- condensing, the exhaust being run to the main exhaust header and from thence to the feed water heater or the free exhaust as conditions demand.

CONDENSERS.

The condensing apparatus consists of two No. 7 Westinghouse Leblanc condensers. They are each capable of handling from 20,000 to 25,000 pounds of steam per hour with the cooling water at 70° F and will maintain a vacuum of 28 inches or better under such conditions.

This type of condenser is really a barometric condenser in which the tail pipe is replaced by a centrifugal pump. The air is taken out by a rotary or centrifugal air pump using water slugs as pistons. These slugs are shot down through an injector tube and carry the air in front of them. The base discharge pump (tail pipe pump) and the air pump are mounted together on a horizontal shaft, and form part of the base of the condenser. They are driven by a non-condensing steam turbine, exhausting to the main exhaust header.

The cooling water and air pump water are taken directly from the tail race through 9 inch and 6 inch lines respectively, each being fitted with ample sized strainers. The pumps discharge through pipes in the south retaining wall into the river. The free or atmospheric exhaust is also run through the south retaining wall.

STEAM PIPING.

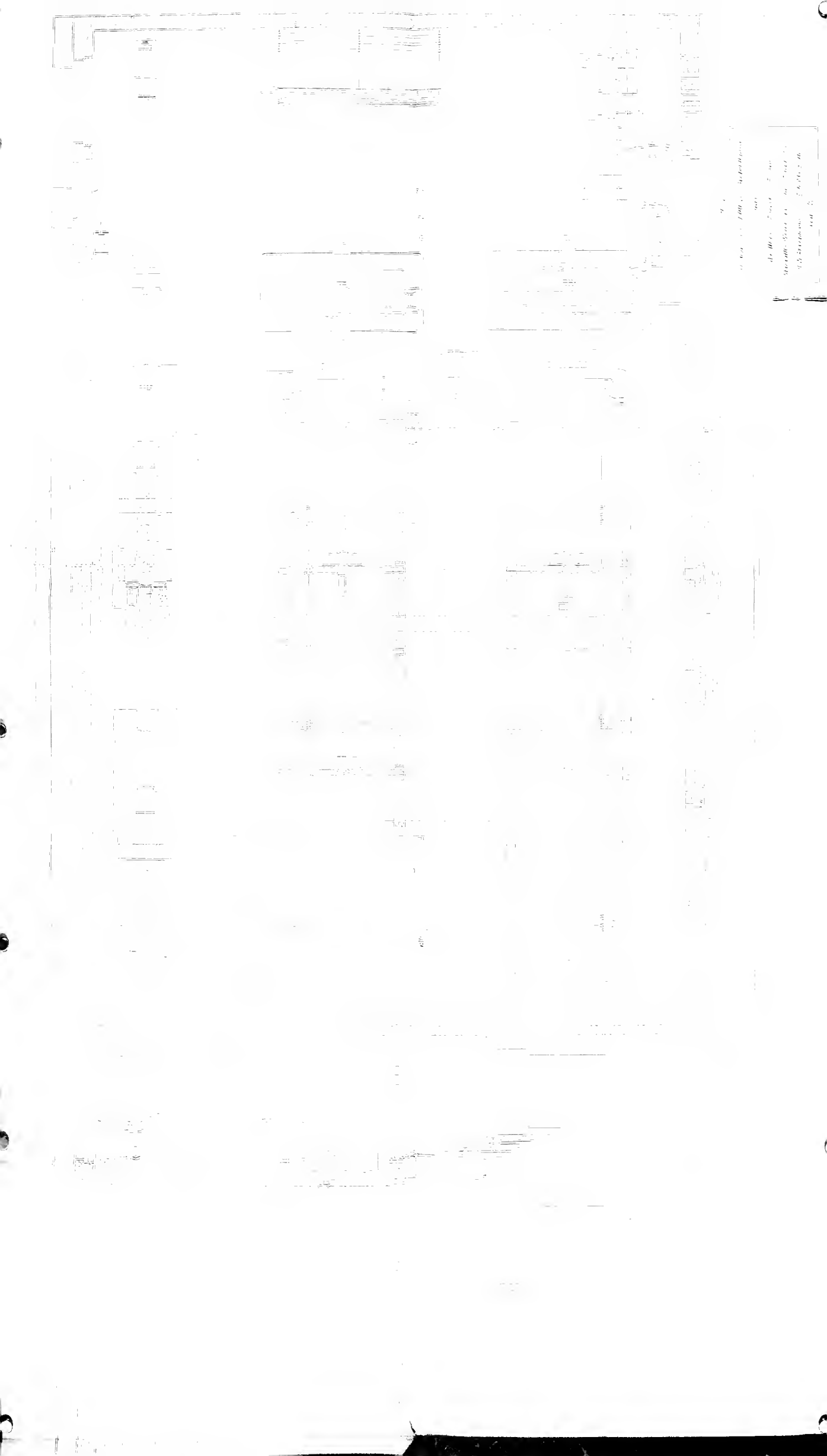
A 7 inch line runs from each boiler to a 14 inch header, the spider system and the resulting short header being used. Each boiler lead has a non-return valve and a straightway or gate valve. The 14 inch header is not anchored but is simply placed on a pair of rollers on the back of boiler No. 1. From this main header there are two main leads and a small lead to the stoker engine. The 750 K. W. turbines are supplied through an 8 inch steam line, tapering off to 6 inch line. This is a high velocity main. The second lead runs to a 5 inch auxilliary header on the south wall which supplies steam through a 3 inch lead to the condenser pump turbines, through a 3 inch lead to the blower engine, and through 1 inch and 3/4 inch pipes to the 12"x 8"x 12" and the 6"x 8"x 12" steam pumps. A lateral in the line from the main to the auxil iary header supplies steam to the exciter turbine. The details of the above are shown on an accompanying drawing.

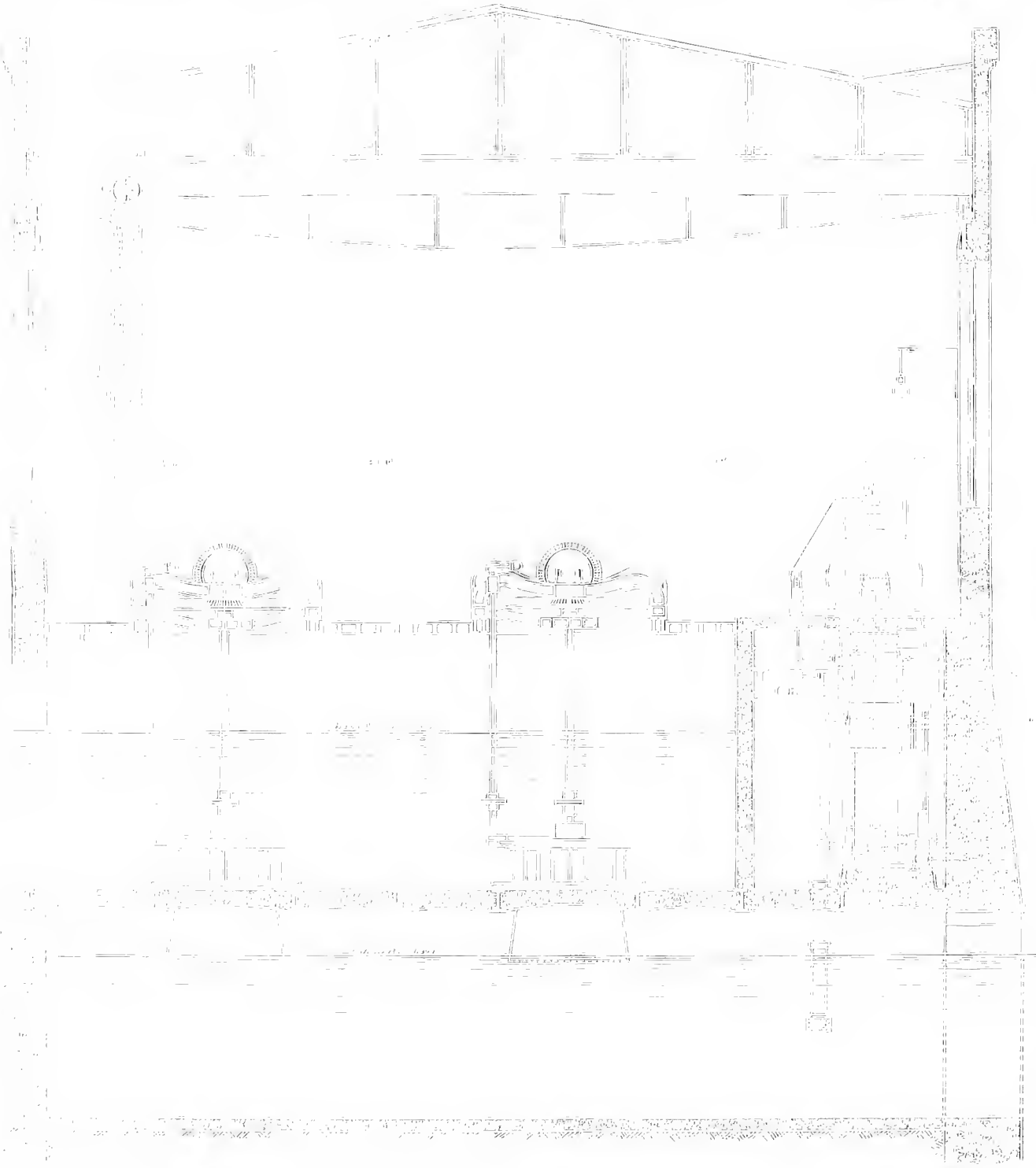
EXHAUST PIPING.

A main header 10 inches in diameter has leads from the auxil iaries as follows: 6 inch lead from exciter turbine; 7 inch lead from condenser pump turbines; 3 1/2 inch lead from blower engine; 1 1/2 inch and 1 inch lead from the pumps and a 1 inch lead from the stoker engine. A 10 inch vertical exhaust pipe runs from this header to the atmosphere through a back pressure valve.

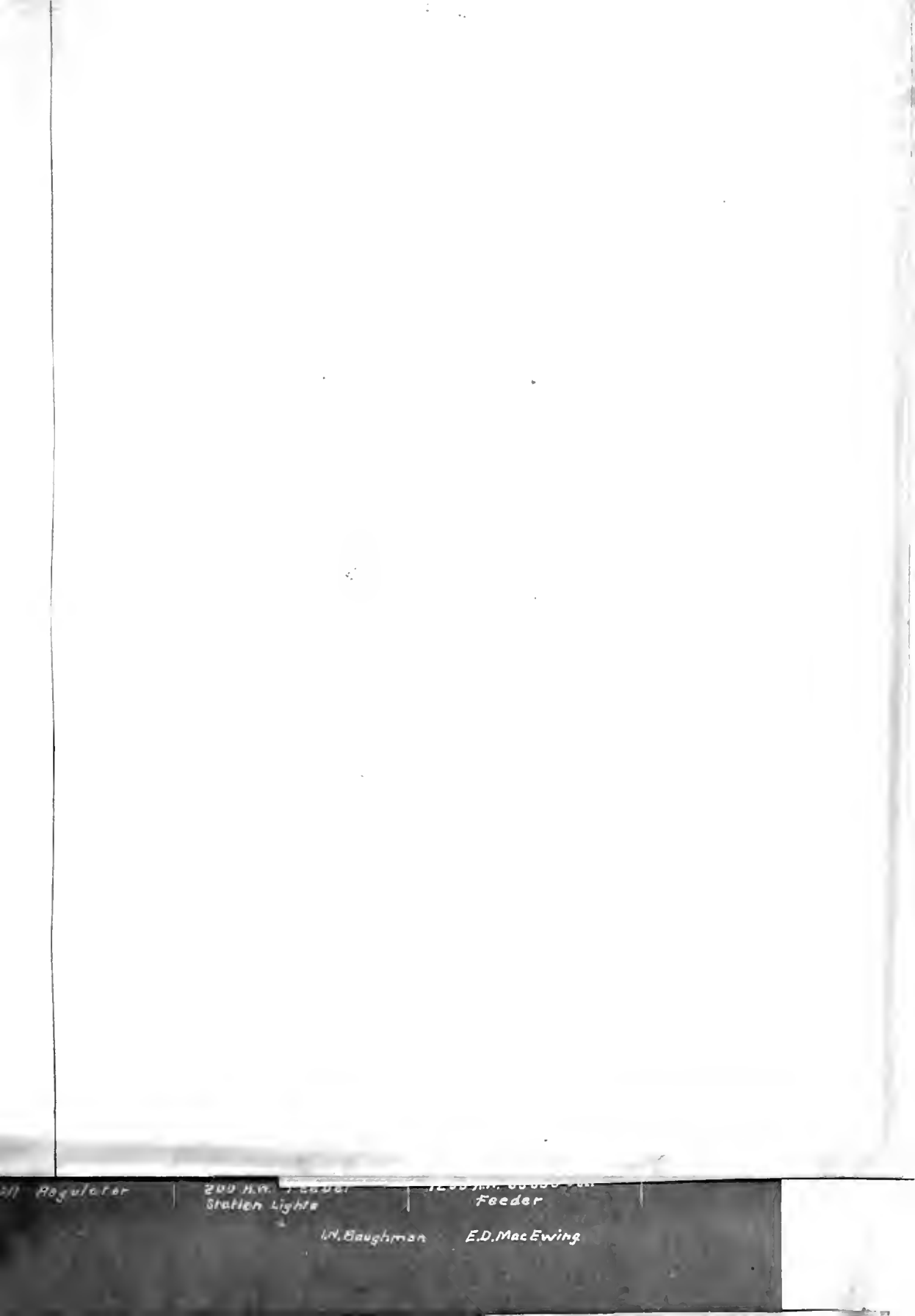
Through valves are used in conjunction with this exhaust pipe and the feed water heater so that the heater's supply of exhaust steam may be regulated to suit the conditions.

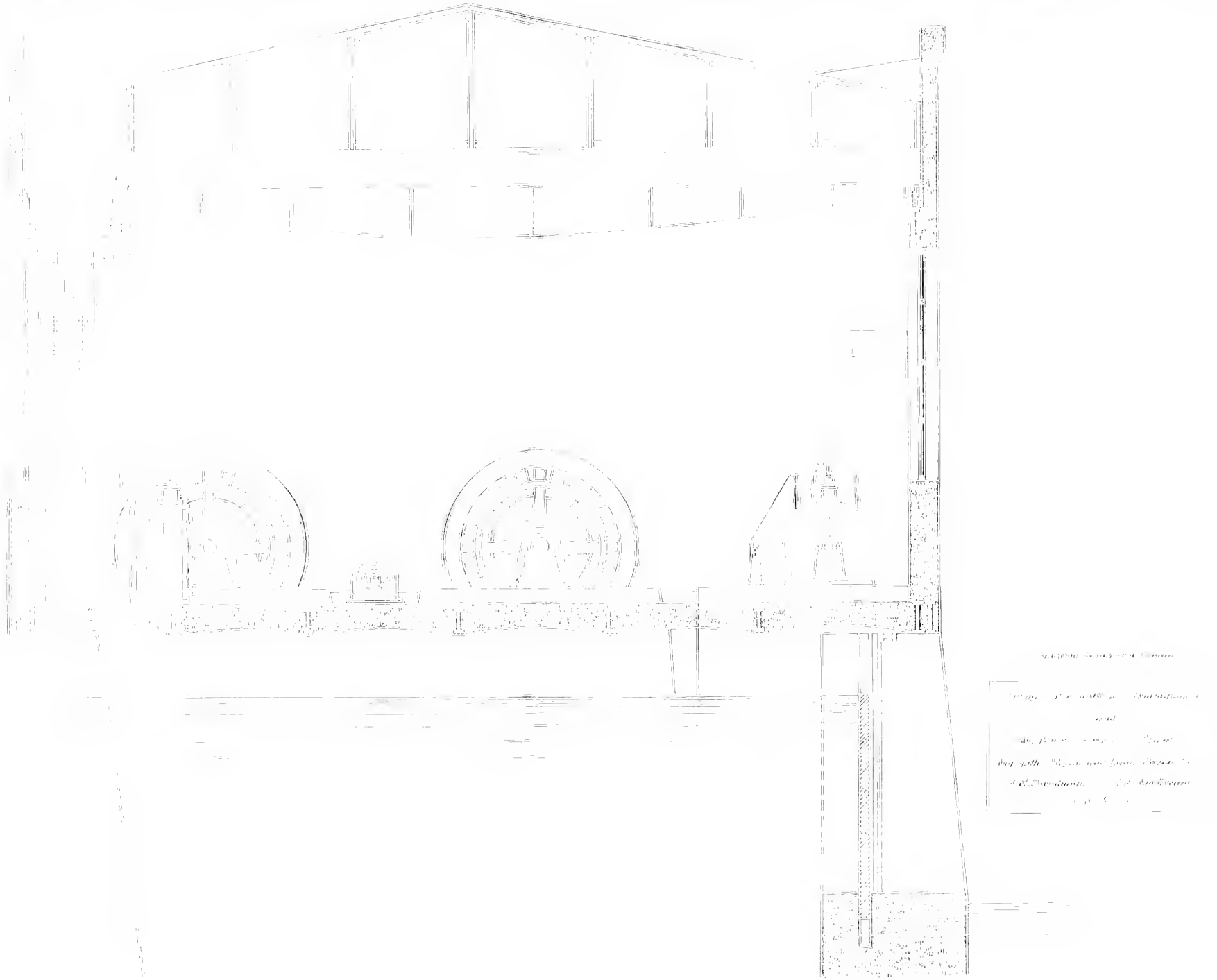
Details of the above may be found in an accompanying drawing.

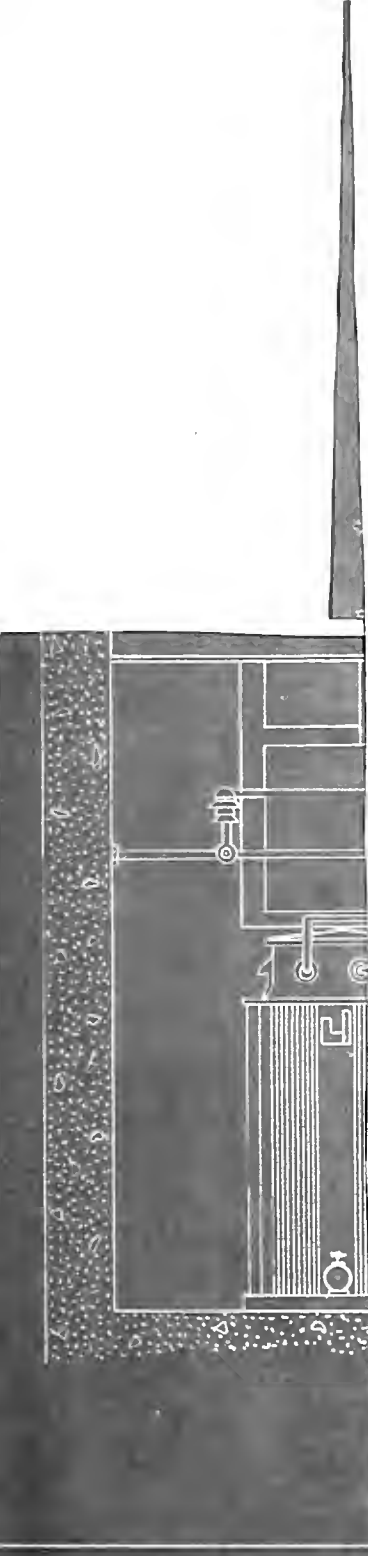





rill Regulator
Station Lights
Feeder
W. Boughman
E.O. MacEwing


Regulator
Station Lights
Feeder
I.N. Baughman
E.D. MacEwing





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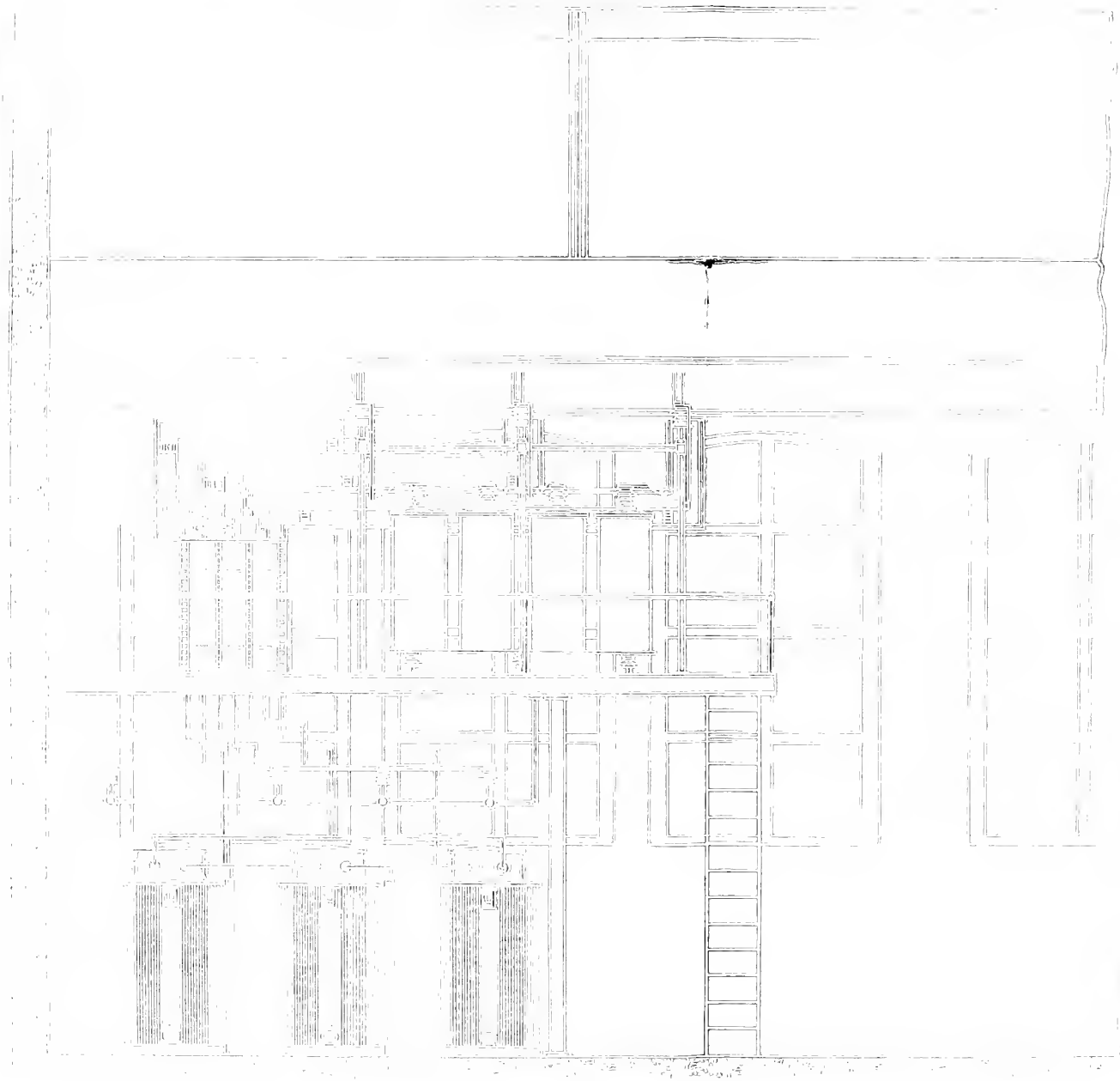
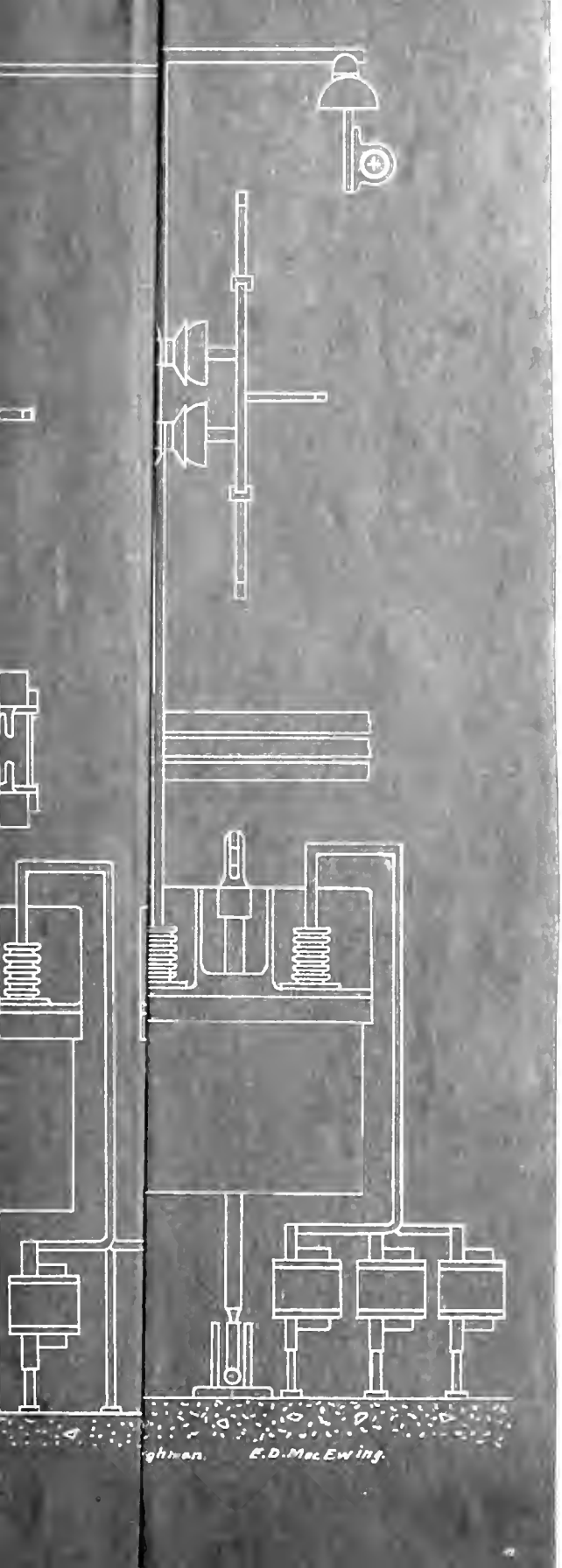
I.N. Boughman E.D. MacEwing




Drill Regulator
200 H.P. Feeder
Station Lights
L.N. Baughman
E.D. MacEwing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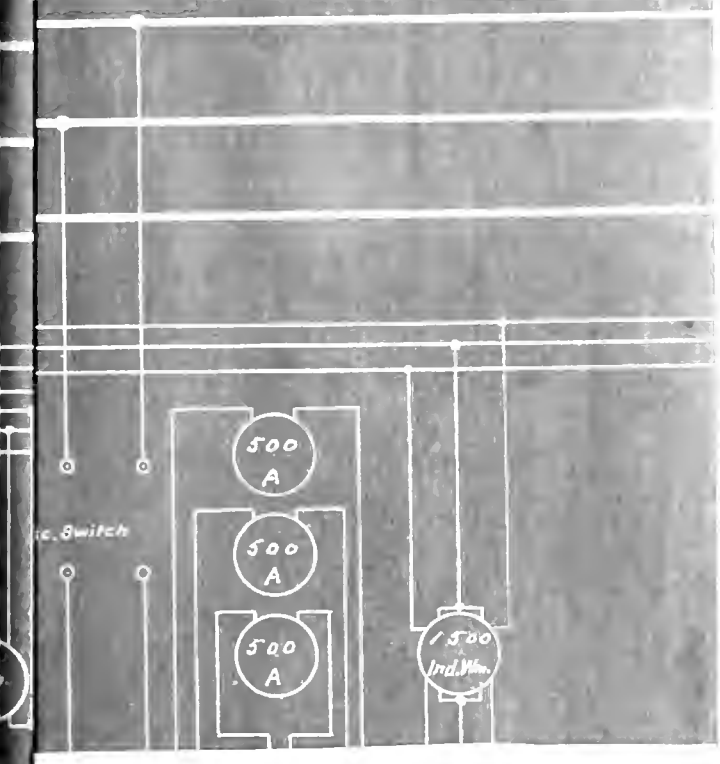
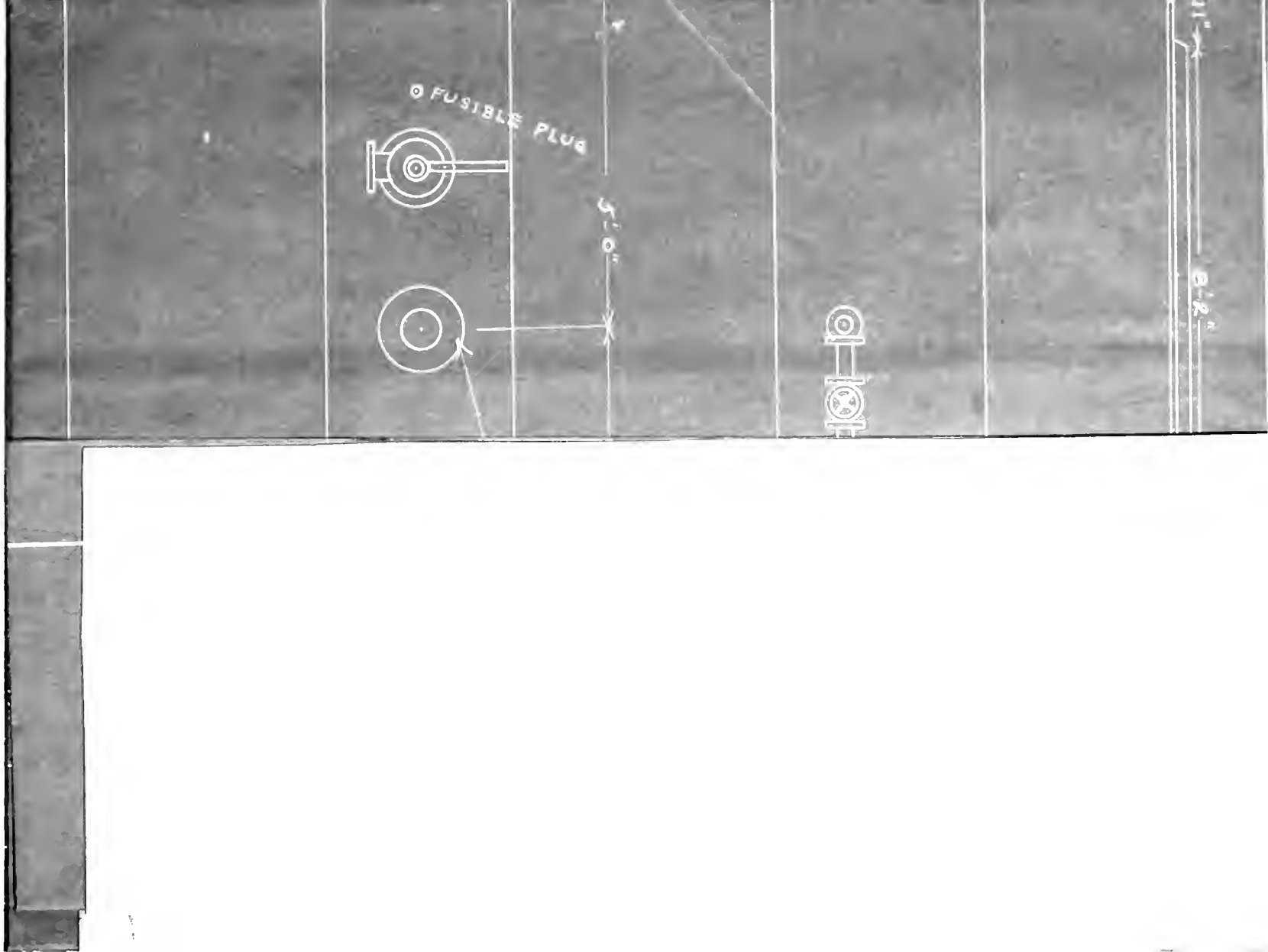
E.D. MacEwing.


500
A
500
A
500
A
1500
Ind. Wm.
ic. Switch


FUSIBLE PLUG
6'-0"
6'-2"